Fact sheet: Small, anastomosing, lowland rivers

General description

Valley- and planform	The valley form varies from a no distinctive valley to a wide U-shaped valley and the channel planform consists of a multiple channel river characterized by vegetated or otherwise stable alluvial islands that divide flows. Each channel in itself can have a straight/sinuous to a more meandering planform.
Hydrology	In the natural situation entrenchment of the channels is minimal and the floodplain is completely inundated during floods. Anastomosing, lowland rivers can be permanent or some channels maybe intermittent. The hydrograph is (moderately) dynamic.
Morphology	The channels are laterally stable due to stabilizing vegetation in combination with relatively low stream power. The erosion-sedimentation processes are only local. Channel formation is slow due to channel sedimentation, the formation of vegetation or ineffective flow due to the very low channel gradient. The channel banks are irregular, mainly shaped by tree roots. The river bottom is dominated by mineral and organic silt, and fine and coarse particulate organic matter (e.g. fallen leaves), mosses, local stands of vascular hydrophytes and course woody debris (logs, debris dams).
Chemistry	Depending on the age and channel slope the floodplain has become organic (peat formation) and the pH can vary from 4.5 to 7. The water quality is mesotrophic.
Riparian zone	The floodplain is dominated by deciduous swamp forest. The river channels are accompanied by mainly *Alnus* trees that more or less fully shade the river beds.

Photo: Small, anastomosing, lowland river in Poland.

Pressures

Major pressures

The prevailing hydromorphological pressure in small, anastomosing, lowland rivers is drainage of the floodplain and channelization, in combination with flow alteration (resulting from impoundment and drainage of agricultural and urban lands elsewhere in the catchment), and alteration of the riparian and floodplain vegetation.

Score of pressure level imposed on small, anastomosing, lowland rivers categorised according to pressure category and pressure, respectively (score in comparison to other pressures within this river type: No = no pressure/stress, L = low pressure/stress, M = moderate pressure/stress, H = high pressure/stress).

Pressure category	Pressure	Score
Point sources	Point sources	H
Diffuse sources	Diffuse sources	H
Water abstraction	Surface water abstraction	M
	Groundwater abstraction	H
Flow alteration	Discharge diversions and returns	L
	Interbasin flow transfer	No
	Hydrological regime modification including erosion due to increase in peak discharges	H
	Hydropeaking	No
	Flush flow	M
	Impoundment	H
Barriers/Connectivity	Artificial barriers upriver from the site	M
	Artificial barriers downriver from the site	M
Channelization	Channelisation / cross section alteration (e.g. deepening) including erosion due to this	H
	Sedimentation	M
Bank degradation	Bank degradation	H
Habitat degradation	Alteration of riparian vegetation	H
	Alteration of in-rivers habitat	L
Others	Maintenance	H
	Exotic species	L

Problems and constraints for river restoration

Floodplain drainage and channelization strongly lower the ground and surface water levels. Side channels will become intermittent or will dry up. Due to downstream channelization the main channel will incise with further water level lowering and drying up of the floodplain. More dynamic flows will scour the river bed and change it to a more mineral system.

Clearing of riparian forests reduces the bank stability and the amount of course woody debris in the channels and lowers the amount of shade which results in higher temperatures and temperature dynamics, more macrophyte growth and potential bank erosion. Incision of the main channel bed due to channelization and flow alteration will strongly reduce the hydrological connectivity between river and floodplain.

Depending on the catchment (ground)water abstractions can also play an important role in river flow alteration. Groundwater abstractions may lower the discharge of rivers, thereby decreasing the flow velocity and water depth with further terrestrialisation of smaller channels.

In many cases maintenance consisting of removing of aquatic vegetation and/or dredging is performed to counteract effects of macrophyte development and channel obstruction.

Apart from hydromorphological pressures these lowland rivers often suffer from eutrophication and organic pollution resulting from a high proportion of agricultural land use upstream in the catchment.

Measures

Common restoration practice

There is little literature available on measures taken to restore small, anastomosing, lowland rivers. Probably this is because of the high costs of floodplain wide measures that include either buying of land or changing land use due to a strong raise in ground water level. Thus, measures that deal with the whole floodplain are rare, but when taken always in combination combined with in river or channel planform measures. The length of a restored stretch is mostly limited to a lower part of the valley. In ideal cases the processes that result in multiple channels are restored. Active multiple channel initiation lacks.

Score per measure category/measure of relevance, effect in-river, effect on the floodplain and costs the measure in comparison to other measures within this river type (No = no relevance or effect, L = low relevance or effect, M = moderate relevance or effect, H = high relevance or effect of the measure) and indication a prioritisation of measures (L = low priority, M = moderate priority, H = high priority).

Measure category	**Measure**	**Relevance**	**Effect in-channel**	**Effect floodplain**	**Costs**	**Prioritisation**
Decrease pollution	Decrease point source pollution	L	L	M	H	L
	Decrease diffuse pollution input	H	M	H	H	H
Water flow quantity	Reduce surface water abstraction	H	M	H	L	H
	Improve water retention	H	M	H	H	H
	Reduce groundwater abstraction	H	M	H	M	H
	Improve water storage	H	M	H	H	H
	Increase minimum flow	H	H	H	H	H
	Water diversion and transfer	M	M	M	H	M
	Recycle used water	H	M	H	H	H

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Costs	Prioritisation
	Reduce water consumption	H	M	H	H	H
Sediment quantity	Add/feed sediment	L	M	L	M	L
	Reduce undesired sediment input	L	M	L	M	L
	Prevent sediment accumulation	L	L	M	M	L
	Improve continuity of sediment transport	M	M	M	M	M
	Trap sediments	L	M	L	M	L
	Reduce impact of dredging	H	M	H	M	H
Flow dynamics	Establish natural environmental flows	H	H	H	H	H
	Modify hydropeaking	No				
	Increase flood frequency and duration	H	M	H	H	H
	Reduce anthropogenic flow peaks	H	M	H	H	H
	Shorten the length of impounded reaches	L	L	No	L	L
	Favour morphogenic flows	M	M	M	M	M
Longitudinal connectivity	Install fish pass, bypass, side channels*	H*	M*	H*	L*	H*
	Install facilities for downriver migration	No				
	Manage sluice, weir, and turbine operation	No				
	Remove barrier	H	H	H	M	H
	Modify or remove culverts, syphons, piped rivers	H	H	H	M	H
In-channel habitat conditions	Remove bed fixation	H	H	H	M	H
	Remove bank fixation	H	H	H	M	H
	Remove sediment	L	L	L	M	L
	Add sediment (e.g. gravel)	L	L	L	M	L
	Manage aquatic vegetation	M	M	M	H	M
	Remove in-channel hydraulic structures	H	H	H	M	H
	Creating shallows near the bank	L	L	L	M	L
	Recruitment or placement of large wood	M	M	L	H	H
	Boulder placement	No				
	Initiate natural channel dynamics	H	H	M	L	H
	Create artificial gravel bar or riffle	L	L	No	M	L
Riparian zone	Develop buffer strips to reduce nutrients	H	H	H	M	H
	Develop buffer strips to reduce fine sediments	M	M	M	M	M
	Develop natural vegetation on buffer strips	H	H	H	M	H

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Costs	Prioritisation
River planform	Re-meander water course	M	M	M	H	M
	Widening or re-braiding of water course	H	H	H	M	H
	Create a shallow water course	H	H	H	M	H
	Narrow over-widened water course	H	H	H	M	H
	Create low-flow channels	H	H	H	M	H
	Allow/initiate lateral channel migration	H	H	H	M	H
	Create secondary floodplain	H	H	H	M	H
Floodplain	Reconnect backwaters, oxbow-lakes, wet-lands	H	H	H	M	H
	Create backwaters, oxbow-lakes, wetlands	H	H	H	M	H
	Lower embankments, levees or dikes	H	M	M	L	M
	Replace embankments, levees or dikes	H	M	M	L	M
	Remove embankments, levees or dikes	H	M	M	L	M
	Remove vegetation	L	L	M	L	L

Problems and constraints with common restoration practice

The most often applied measure in anastomosing, lowland rivers is lowering the floodplain in combination with a shallow stream bed whereby the stream can shape the floodplain, rewet it and form multiple channels. remeandering. Active anastomosing did not occur yet. The major problem is the rise of te ground water table in the floodplain, necessary for recovery processes but mostly limited by other societal interests.

Hydrological measures are more often only applied along river stretches in low to zero slope areas without considering the hydrological dynamics that results from catchment wide activities, like drainage, water abstraction and paved surfaces.

Giving room for free swamp forest development also meets a lot of resistance from other users of the floodplain.

Promising and new measures

In general, multiple channels do not differ much in in-channel features compared to single channels. The most important difference are of course the semi-aquatic to terrestrial patches between the channels. Restoring anastomosing, lowland rivers implies an integrated restoration of the floodplain and extends much further into a catchment in comparison to a single-thread river.

Restoration of small, anastomosing, lowland rivers is until now an underestimated possibility for lowland river valley restoration. By restoring processes that create a two to multiple channel pattern in a rewetted area or by even actively creating a multiple channel pattern three major objectives can be reached at the same time; 1) the rewetted area can serve as a large water retention area for water safety downstream, 2) the multiple channel network provides a higher water flow through area then one single channel and has a has a higher width : depth ratio, 3) the biodiversity in a gradient of channels, swampy banks and wet higher 'islands' is much higher.

The chances of reaching a stable multiple channel network that is controlled by vegetation, as is the case for small, anastomosing, low energy rivers in the lowlands, is highest in stretches of the river where the slope is low to near zero. Historically, here swamps or bogs occurred. Remains of former bogs are recognizable in stream valley-peatlands. Such swampy areas can develop either in anastomosing rivers or in flow-through swamps depending on the flood frequency and intensity.

Restoring small, low energy, anastomosing rivers with either two or more channels starts with a catchment analysis. A number of features of these systems should be kept in mind to reach a successful approach:

- A stable anastomosing channel system with biotic channel spanning obstructions.
- Overbank flows occurs regularly, for longer duration, and with larger magnitude compared to a meandering system.
- Avulsions are the main mechanism for channel change; primary and secondary avulsions occur with new dam formation, like obstructions through vegetation overgrowth, and during overbank flows.
- Channel migration is a secondary mechanism for channel change; less cohesive sediment and less stabilizing vegetation in a more or less continuous wet environment (water almost year round at or above mowing level) create a more dynamic environment.
- There is more sediment deposited in the channel behind plant, logs or beaver dams and much fine sediment is deposited in the floodplain as a result of more frequent overbank flows; sedimentation is heterogeneous.
- There are lower energy flows (less high peak flows), but overbank flows affect a larger area and saturate the ground.
- The riparian zone extends across the valley, past the channel closest to valley edge; a higher water table across the valley supports riparian vegetation.
- The wetter environment promotes growth of riparian shrubs and graminoids.
- Fine sediment increases bank cohesion; a mix of riparian and shrubs and graminoids increases bank stability.

To create a more riparian wetland type of environment along a very low gradient trajectory of the small stream, a downstream obstruction is needed. Such obstruction can be natural or engineered (Figure 1).

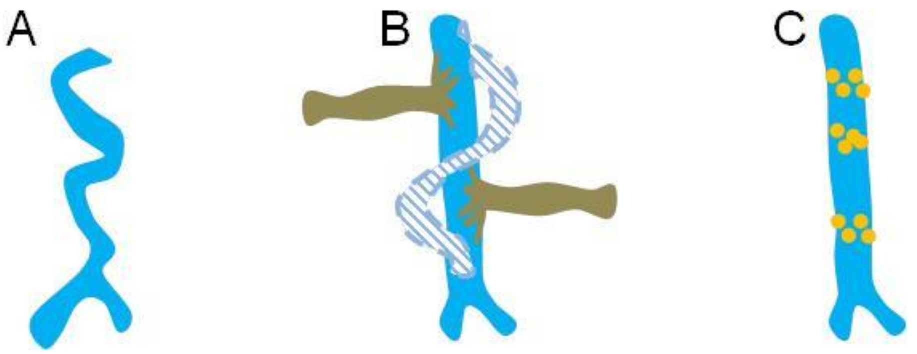

Figure: A flow retarding or obstructing structure can be a meandering river stretch (A), a by introduced logs initiated meandering stretch with a preferably smaller wet area (B), or a weir like construction made of a cascade from stones or logs that simultaneous act as fish passage.

The anastomosing channel system can occur in different shapes (Figure 2).

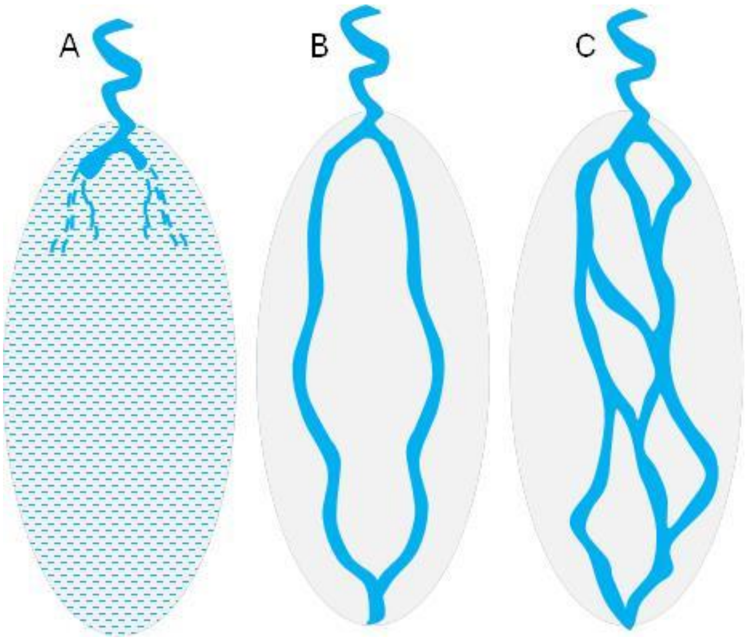

Figure: The anastomosing river valley can look like a flow through wetland either or not forested (A), a wetland either or not forested with two channels (B), or a wetland either or not forested with an anastomosing channel network.

Monitoring scheme

Monitoring schemes should follow some basic principles that apply to all river types:

- Biotic as well as abiotic variables should be monitored. The restoration measures might have succeeded to create the desired habitats but the effect on biota might be limited due to other pressures at larger scales which have not been addressed in the restoration project.
- In-channel, riparian, as well as floodplain conditions should be monitored. Besides the biological quality elements relevant for the Water Framework Directive, restoration can also have positive effects on other semi-aquatic and terrestrial organism groups, like ground beetles and floodplain vegetation. Indeed, there is empirical evidence that effects on other organism groups can be larger.
- Monitoring has to be conducted at appropriate spatial and temporal scales that reflect (i) the habitat needs of the organisms (e.g. monitoring microhabitat substrate patches for macroinvertebrates, mesohabitat features for fish), (ii) all life stages (e.g. monitoring in-channel and riparian habitats for macroinvertebrates with terrestrial life-stages), (iii) and the reproductive cycle as well as dispersal abilities (long-term monitoring to also cover effects of restoration on long-lived species and weak dispersers).
- Looking at the spatial and time scale of many current restoration measures macro-invertebrates are most suited for river monitoring. Fish population are strongly managed and reflect larger scale conditions, macrophytes bear a long history as they disappear only slowly and algae reflect to short time scales and very, very

local conditions. Floodplains are large scaled and best be monitored by vegetation. Riparian zone can be monitored by using vegetation or carabid beetles.

- A Before-After-Control-Impact design should be applied to allow disentangling the effect of restoration from general trends in the whole river or catchment.
- However, the final selection of the organism groups, and spatial / temporal scales monitored strongly depends on the objectives and applied measures. Of course, it is reasonable to focus on the abiotic and biotic variables and scales that potentially have been affected by the restoration measures (e.g. in-channel habitat conditions by in-channel measures).
- Monitoring results should be used for adaptive management, i.e. to react on unanticipated effects and trends, and this should be included in the planning from the beginning ("Plan-B").

For further reading and practical guidelines we refer to the handbook of the River Restoration Centre (River Restoration Centre 2011).

The relevance of a variable at the scale of the river, riparian zone and floodplain scored in comparison to other variables within this river type (No = no relevance, L = low relevance, M = moderate relevance, H = high relevance)

Variable group	**Variable**	**River**	**Wetland zone**	**Floodplain**
River and wetland hydrology		H	H	H
Wetland and in-river hydraulics		H	H	L
Floodplain and wetland morphology		L	H	M
Wetland and in-channel morphology	Profile (longitudinal, transversal)	H	No	M
	Meso-/micro-structures	M	M	No
Chemistry	Nutrients	H	H	L
	Toxicants	H	H	L
	Others			
Biology	Algae	L	L	No
	Macrophytes	M	H	No
	Macroinvertebrates	H	H	No
	Fish	M	L	No
	Floodplain/riparian vegetation	L	H	H
	Terrestrial fauna	No	H	M